# COATINGS AND ENAMELS

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## GLASS ENAMEL FOR STEEL BASED ON DIATOMITE MATERIAL

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The possibility of replacing quartz sand for melting enamel frit by natural diatomite rock is investigated. It is established that the use of local diatomite as the silica material in melting enamel frits is a promising trend in enameling technology. The properties of frits based on diatomite materials are similar to the properties of the reference low-melting frit F-1; they have have slightly lower softening and melting temperatures, and their technological characteristics are within the limits specified by GOST 24495–80 for undercoat enamel on steel.

At present when competitiveness of products is the critical factor in production, it is essential to lower production cost and energy consumption. Consequently, it is advisable to use natural minerals for technical enameling, where the quality of the coating is significant and not its aesthetic effect, since mineral materials, especially from local deposits, are significantly less expensive.

A promising mineral variety for producing technical enamels is diatomite from the Irbitskoe and Kamyshlovskoe quarries in the Sverdlovsk Region. The average chemical composition of the considered rocks (Table 1) indicates that they can be used as aluminosilicate material for producing glass enamel. X-ray phase analysis shows high amorphousness of the main components of diatomite rocks.

The purpose of this study is to investigate the possibility of using mineral diatomite instead of quartz sand in producing undercoat enamels intended for application on steel pipes.

Enamel frits were melted in a batch silit furnace at a temperature of 1000 ± 10°C. The weight of a melted frit portion was 200 g, the complete melting lasted 3 – 3.5 h, and the gas emission was moderate. Three compositions were investigated (Table 2); enamel F-2 was taken as the reference standard, composition No. 1 is the one where $SiO_2$ is introduced by Irbitskoe diatomite, and composition No. 2 contains Kamyshlovskoe diatomite.

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**TABLE 1**

| Diatomite | Weight content, % | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | CaO | MgO | $Al_2O_3$ | $K_2O + Na_2O$ | $Fe_2O_3$ | $TiO_2$ | calcination loss |
| Irbitskoe | 72.00 | 0.95 | 1.36 | 8.20 | 2.10 | 3.92 | 0.40 | 13.07 |
| Kamyshlovskoe | 75.40 | 1.90 | 0.80 | 9.00 | 2.20 | 4.10 | – | 6.60 |

**TABLE 2**

| Frit composition | Weight content, %* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $B_2O_3$ | $Al_2O_3$ | CaO | $Na_2O$ | $K_2O$ | $Co_2O_3$ | NiO | MnO | MgO | $Fe_2O_3$ |
| F-1 | 39.51 | 22.06 | 5.64 | 6.82 | 22.27 | – | 0.62 | 1.54 | 1.74 | – | – |
| No. 1 | 38.65 | 21.08 | 4.40 | 6.77 | 21.78 | 0.68 | 0.61 | 1.51 | 1.70 | 0.73 | 1.79 |
| No. 2 | 41.43 | 21.90 | 5.00 | 1.05 | 22.54 | 0.62 | 0.62 | 1.53 | 1.73 | 0.45 | 2.28 |

* Also, frit No. 1 contains 1.79% $TiO_2$. All compositions contain 4.38% F (above 100%).

**TABLE 3**

| Frit composition | CLTE, $10^{-7}$ K$^{-1}$, in temperature interval of 40 – 400°C | Temperature, °C | | Viscosity, $10^{-10}$ Pa · sec at temperature 545°C | Surface tension, $10^{-3}$ mN/m | Adhesion, mN/m$^2$ | Spreadability, mm |
|---|---|---|---|---|---|---|---|
| | | transformation | softening | | | | |
| F-1 | 89.29 | 439.0 | 502.0 | 11.0 | 213.0 | 214.7 | 48 |
| No. 1 | 114.70 | 387.5 | 429.0 | 10.5 | 191.9 | 193.5 | 49 |
| No. 2 | 103.50 | 353.0 | 425.0 | 11.0 | 192.2 | 193.8 | 40 |

The physical and technological characteristics of frits were measured and the temperature-time conditions for firing slip made of the considered enamels were determined (Table 3).

The CLTE was studied on a quartz dilatometer. The CLTEs of the obtained frits are within the interval specified for undercoat enamels by GOST 24405–80. It can be seen from Table 3 that the CLTE of enamels using diatomite is slightly higher than in the reference enamel F-1, which can be attributed to their high content of iron, potassium, and magnesium oxides, which are not present in the reference enamel. The transformation and softening temperatures in mixtures with diatomite are nearly 70% lower than in the reference standard. This suggests a substantial effect of the silicate material structure on the fusibility of enamel.

It has been shown earlier [1] that partial or full replacement of quartz sand by amorphous varieties of silica makes it possible to shorten by 8 – 10 times the duration of silicate and glass-formation stages in glass melting and decrease by 3 – 4 times the total melting duration, which intensifies the glass melting process and decreases the power consumption. The obtained results suggest that the presence of amorphous silica in diatomite not only intensifies enamel frit melting due to the high chemical activity of diatomite caused by adsorption of hydrated alkali and alkaline-earth carbonates on the extended amorphous surface of the mineral phases of diatomite, but also lowers the softening temperature of finished enamel frit.

A high-quality enamel coating to a large extent depends on the spreading characteristics of its frit that are estimated based on surface tension, adhesion, viscosity, and spreadability of enamel on a steel substrate surface. The measurement results shown in Table 3 report similar viscosity values determined by the indentation method for all frits. The surface tension and adhesion were determined by the method of a drop lying on a substrate. The highest values are seen in the reference composition F-1, whereas these characteristics in compositions Nos. 1 and 2 are slightly lower, which is related to the presence of iron oxides. The surface tension of all considered frits is within the limits of 180 – 350 mN/m, and the spreadability of frits is within the interval of 30 – 55 mm specified for undercoat enamels according to the requirements of GOST 24405–80.

To study the temperature-time conditions of firing enamel frits, we used slip of the following composition (wt.%): 100 frit, 20 quartz sand, 5 Chasov-Yarskoe clay, 0.1 borax, 0.1 potash, and 50.0 water. The slip was milled in a porcelain drum with uralite balls for 30 – 40 min to the fineness of 10 – 15 units of the Lisenko vessel. After aging for 2 days, the enamel slip was deposited on steel samples by immersion, the excessive slip was removed with a brush, then the slip was dried for 10 – 15 min at a temperature of 200 – 250°C. All the enamel compositions after firing formed a smooth even enamel coating. Sufficient adhesion strength was achieved in samples fired for 4 min at 750°C or for 2 min at 800°C.

Thus, the use of Irbitskii or Kamyshlovskoe diatomite as a silicate material for melting enamel frits is a promising trend in enamel technology. The properties of frits produced on the basis of diatomite materials are similar to those of the low-melting reference frit F-1; they have slightly lower melting and softening temperatures and their technological characteristics are within the limits specified by GOST 24405–80 for undercoat enamel applied to steel.

## REFERENCES

1. I. S. Sinevich, "Use of Synthesized Amorphous Silica for Melting Silicate Glasses," *Steklo Keram.*, No. 10, 27 – 28 (1981).